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M3Or4B-04 [Invited]: Cryogenic Integrated Circuits for Quantum Computing

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Superconducting quantum processors are controlled and measured in the analog domain and the design of the associated classical-to-quantum interface is critical in optimizing the overall performance of the quantum computer. Control of the processor is achieved using a combination of carefully shaped microwave pulses and high-precision time varying flux biases. Measurement of quantum states is typically achieved using dispersive readout, which requires a low-power pulsed microwave drive and a near quantum-limited readout chain. For control of a single qubit, a typical system employs two high-speed high-resolution (e.g., 1 Gsps/14 bit) digital-to-analog converters (DACs) and a single-sideband modulator to generate microwave control pulses. A third DAC with similar specifications is used for flux-bias control. A typical readout channel may service on the order of five qubits and contains yet another pair of DACs, with a single-sideband modulator employed to generate a stimulus signal. For measurement, the readout chain also employs a series of cryogenic amplifiers followed by further amplification, IQ demodulation, and high-speed digitization at room temperature. For today's prototype systems with on the order of 50-100 qubits, keeping most of the electronics at room temperature makes sense. However, achieving fault tolerance—a long term goal of the community—will require implementing systems with on the order of 1e6 qubits and today's brute force control and readout approach will not scale to these levels. Instead, a more integrated approach will be required.

In this talk, we will present a review of recent work towards implementing a scalable cryogenic quantum control and readout system using silicon integrated circuit technology. After motivating the work, we will describe key challenges in implementing such a system. Two examples of cryogenic integrated circuits will be presented: ultra-low-power LNAs for qubit readout and low-power CMOS pulse modulators for quantum control. The talk will conclude with a discussion of future work.

Author: BARDIN, Joseph (University of Massachusetts Amherst)

Presenter: BARDIN, Joseph (University of Massachusetts Amherst)

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